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ABSTRACT

A new method to prepare TL dosimeters in solid discs form, by the application of cold press in a mixture of KCl and fluorite in powder form, is investigated. By this method, it is possible to obtain thousands of dosimeters without difficulty much more uniform than that obtained from monocrystal ingots.

The results show that the new dosimeters present the same properties as the fluorite in powder form, with the advantage that it is easier to handle in routine work.

The ratio of 2 to 1 for KCl mass to CaF_2 mass present good TL sensitivity to ionizing radiation and sufficient mechanical resistivity. The minimum detectable exposure is approximately 10 mR.

83% from 442 CaF_2 solid discs gave TL response within 10% of mean value. Energy dependence is also presented.

INTRODUCTION

Nowadays, TL dosimeters are widely used in radiological protection, medicine and personnel monitoring.

Having in mind the use of Brazilian fluorite from Criciuma – Sta. Catarina State – in radiation dosimetry, properties of crystals in powder form were studied[2,4-6]. These studies showed that crystal grains between 85 μ and 185 μ have the maximum TL sensitivity and that an annealing at 580°C for 10 minutes to remove geological TL, followed by another one at 400°C for 2 hours is indicated to produce reproducible TL readings.

The use of powder in routine dosimetry is difficult and a program to produce dosimeters in solid form by cold press process was developped. These results are presented subsequently.

EXPERIMENTAL PROCEDURES

Powdered Green fluorite annealed at 580°C for 10 minutes mixed to KCl of 95% purity was used to produre polycrystalline discs. Both materials have grains sizes between 85 μ and 185 μ.

A Perkin Elmer die and a pressure of 20 000 pounds during 3 minutes was used to produce pellets of 13 mm diameters, and 300 mg mass.

The pellets were, then, annealed at 400°C for 2 hours in air to remove any spurious TL and to stabilize the TL response before irradiations. Between successive exposures an anneal of 400°C for 20 minutes was used.

(*) Trabalho realizado pelo Centro de Proteção Radiológica e Dosimetria, Área de Materiais Dosimétricos, Instituto de Energia Atômica e Instituto de Física da Universidade de São Paulo.

The TLD reader used was mounted in the laboratory[1]. The pan was made with Kanthal steel; the heating rate used was approximately linear of 11°C per sec for temperatures up to ~ 325°C. A TTA, model TP – 2000 temperature programmer coupled to one CON-RAD Thermoluminescence Dosimetry System – Model 5100 was also used. This assembly has linear pan heating rate varying between 0.15°C per second and 15°C per second between room temperature and 600°C.

The mass production of CaF_2 dosimeters is being made with a die which produces 10 pellets at each pressing. Each disc has a diameter of 10 mm, which is suitable for using in the IEA badges. The mass of each disc is ~ 190 mg, ~ 63 mg being of Brazilian fluorite and ~ 127 mg of KCl.

To find the energy dependence of TL of discs a Siemens X ray machine model stabilipan, a Jupiter Junior S ^{60}Co gamma rays therapy machine and a 4 MeV linear accelerator Varian mod. LINAC 4 were used.

The exposures were measured with a Farmer Secondary Standard Dosimeter Type 2502 and the tissue doses calculated from dose measurements and appropriate tables[3].

The effective energy of X rays was determined by the measurements of the half-value layer[3].

A 40 mCi ^{60}Co source was also used to irradiate the dosimeters.

For irradiation the dosimeters were kept inside the badges used in personnel monitoring at the IEA, when necessary. These consist of a plastic box of ~ 4 mm wall, an open window and 0.5 mm Pb filters.

RESULTS

a – Excipient Choice

Materials other than KCl were mixed to fluorite and cold pressed to produce polycrystalline discs to find the most suitable one for routine dosimetry. KCl was found to be most convenient one because it is less hygroscopic and less chemically active and produces a resistent pellet. Grains sizes are the same for fluorite and KCl – between 85 μ and 185 μ.

The ideal ratio between KCl mass and fluorite mass in each pellet is 2, and the total mass for a disc of 13 mm diameter is 300 mg. Increasing the fluorite mass in each disc increases the TL sensitivity but decreases the mechanical resistivity. On the other hand, increasing the KCl mass, increases the resistivity but decreases the TL sensitivity, due to the increase of the dosimeter opacity.

b – Glow Curves

Figures 1 and 2 show respectively the Glow curves of 13 mg fluorite powder and solid pellets of 300 mg obtained using slow heating rates. It is worthwhile to note that the same TL peaks are observed in the glow curve both in powder form and in the polycrystalline disc.

As it is expected, the peaks become higher and displace to higher temperatures with the rising of the pan heating rates.

c – Uniformity of Production

The test of the uniformity of the discs we produced was carried out in 442 discs with 10 mm diameter.

After the annealing at 400°C for 2 hours the dosimeters were exposed to 1.23 R of gamma rays of ^{60}Co

Figure 3 shows the response of the dosimeters, together with the response of 414 LiF: TLD-600 ribbons from one batch produced by the Harshaw Chemical Co.

As can be seen, for both, the CaF_2 discs and the LiF: TLD-600 ribbons, 83% of the dosimeters presented TL readings within 10% of mean value. The standard deviation of the mean value is 7% and 8% for CaF_2 discs and TLD-600 ribbons, respectively.

d – Dose Calibration Curve

Figure 4 shows the variation of TL reading of 300 mg discs with exposure to ^{60}Co gamma rays. The minimum detectable exposure is ~ 10 mR and the response varies linearly from 10 mR to 10^4 mR.

The calibration curve of the 10 mm diameter polycrystalline discs and TLD-700 ribbons contained inside the IEA badges can be seen in figure 5. The linearity was observed from 1 to 100 rads for CaF_2 discs irradiated behind plastic wall of the badge, plastic wall plus lead filter, TLD-700 ribbons – open window and behind plastic wall plus lead filter.

The dosimeters were exposed to 100 KVp, 2 mm Al-X rays (32 KeV eff). One sees that the TL responses behind the Pb filter have great fluctuations, due to the variation of X ray spectra inside the irradiation field during the exposure.

e – Energy Dependence

Figures 6 and 7 show the energy dependence of CaF_2 polycrystalline discs and of LiF TLD-700 ribbons for comparison. Each point is a mean value of 5 different irradiations; bars correspond to standard deviations.

From the figures one sees that lead filter behind the plastic wall of the badge in enough to produce the build up for the ^{60}Co gamma rays

The variation of the ratio of $\frac{\text{TL plastic wall}}{\text{TL Pb filter}}$ with the energy of incident radiation allows the determination of the effective energy. An analysis of the personnel monitoring data using this method is just started and results are not available.

CONCLUSIONS

Results show that polycrystalline discs of fluorite and KCl are inexpensive, easy to be produced, to be handled and efficient to be used in personnel monitoring.

The effect of UV and visible light on the TL of CaF_2 can be avoided, by working under red light as in photographic work.

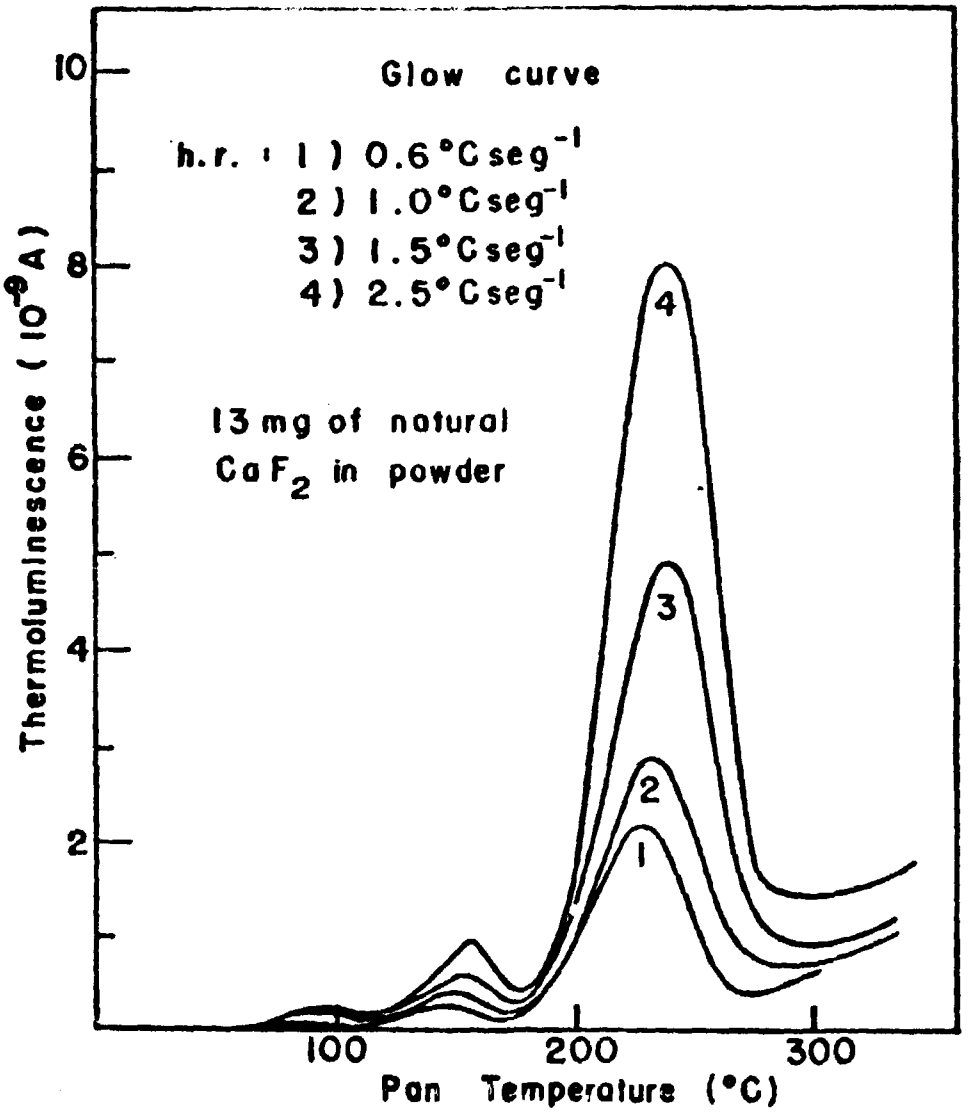
Glow curve
h.r. : 1) 0.6 °C seg⁻¹
2) 1.0 °C seg⁻¹
3) 1.5 °C seg⁻¹
4) 2.5 °C seg⁻¹
13 mg of natural
CaF2 in powder
Thermoluminescence (10⁻⁹ A)
Pan Temperature (°C)
10
8
6
4
2
100
200
300
1
2
3
4

Figure 1

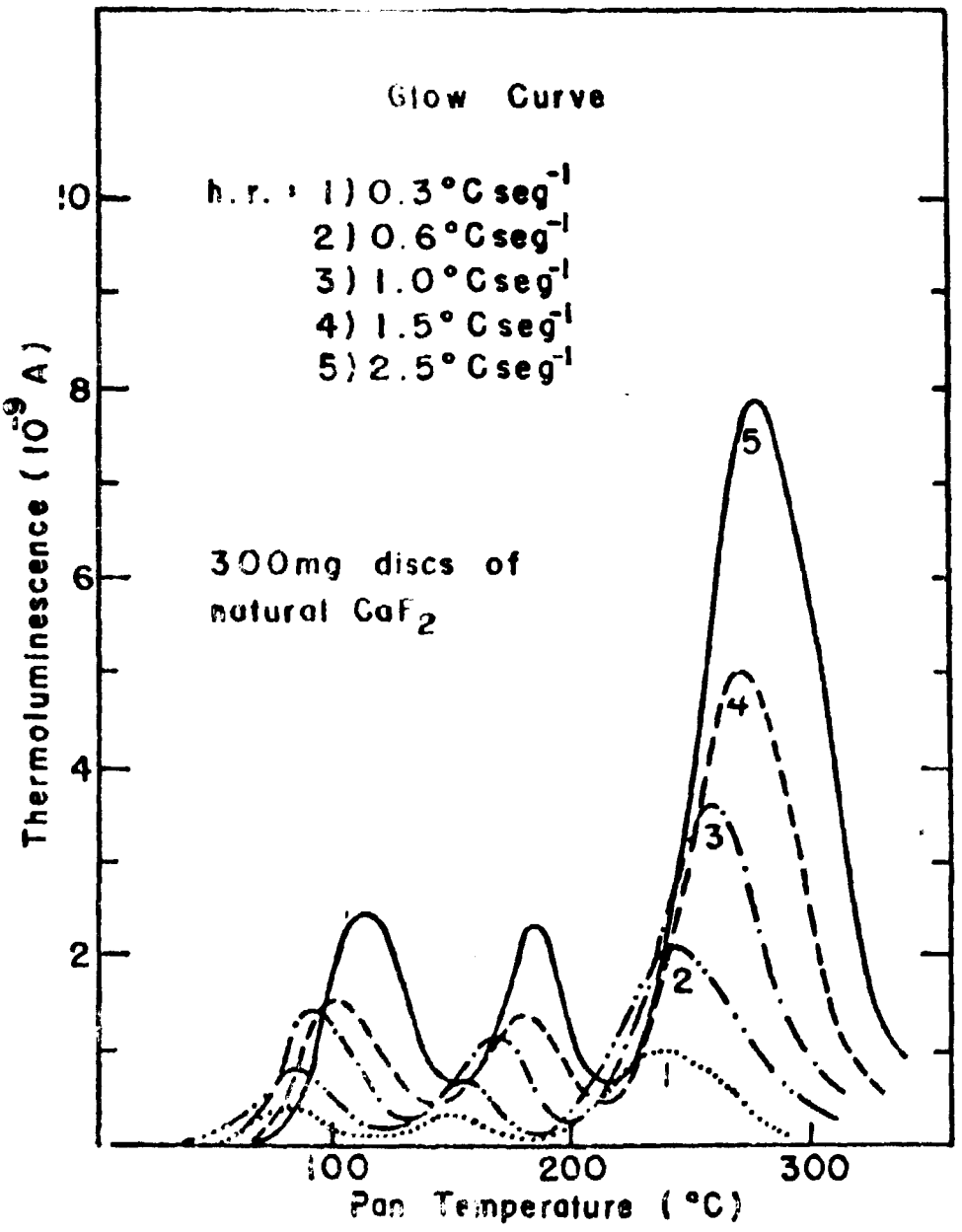
Glow Curve
h.r. : 1) 0.3 °C seg⁻¹
2) 0.6 °C seg⁻¹
3) 1.0 °C seg⁻¹
4) 1.5 °C seg⁻¹
5) 2.5 °C seg⁻¹
300mg discs of
natural CaF2
Thermoluminescence (10⁻⁹ A)
Pan Temperature (°C)
100
200
300
2
4
6
8
10
1
2
3
4
5

Figure 2

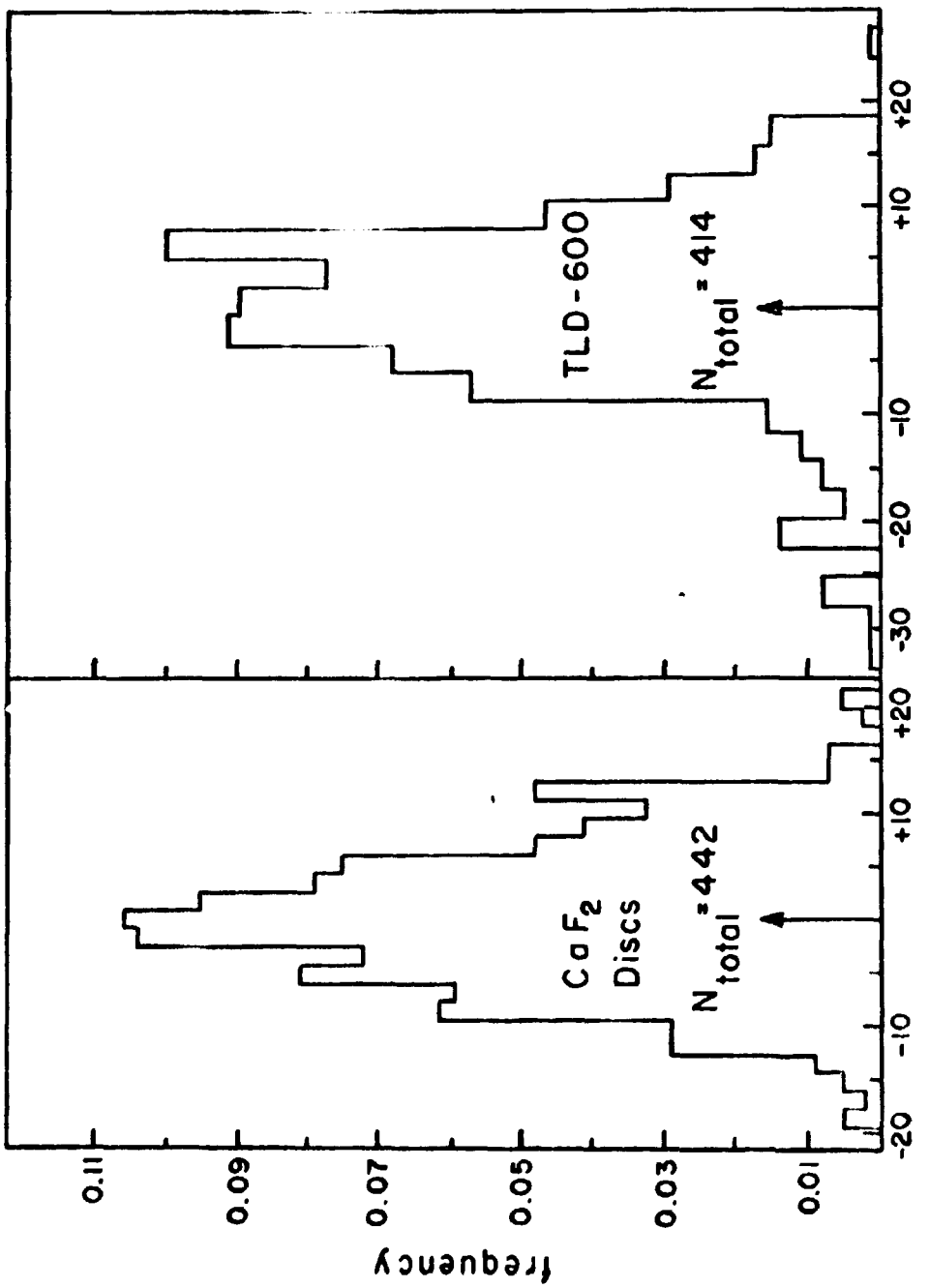
TLD-600
N_{total} = 414
CaF_2 Discs
N_{total} = 442
Frequency
0.11
0.09
0.07
0.05
0.03
0.01
-20
-10
+10
+20
-30
% of mean value

Figure 3

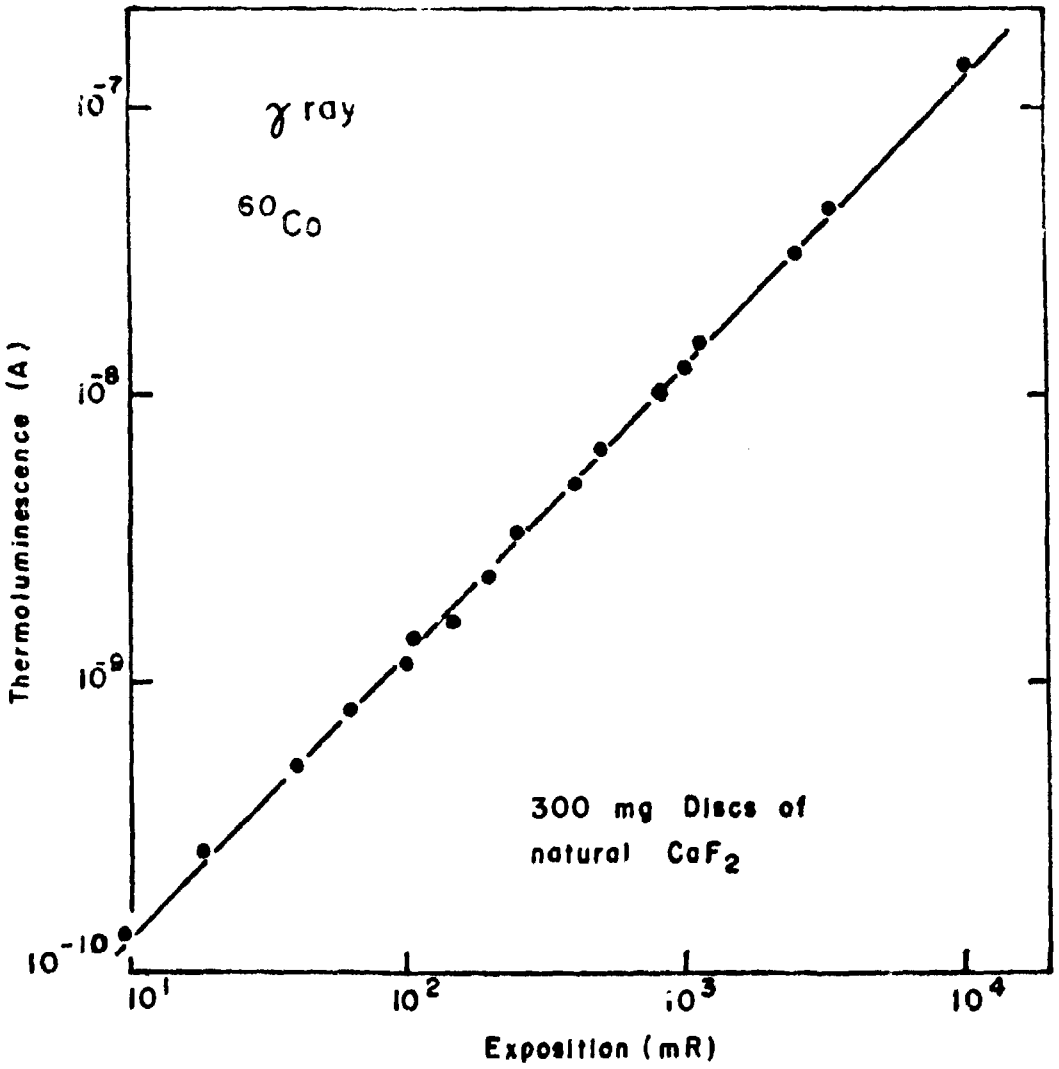
γ ray
60Co
300 mg Discs of
natural CaF2
Thermoluminescence (A)
10-7
10-8
10-9
10-10
10¹
10²
10³
10⁴
Exposition (mR)

Figure 4

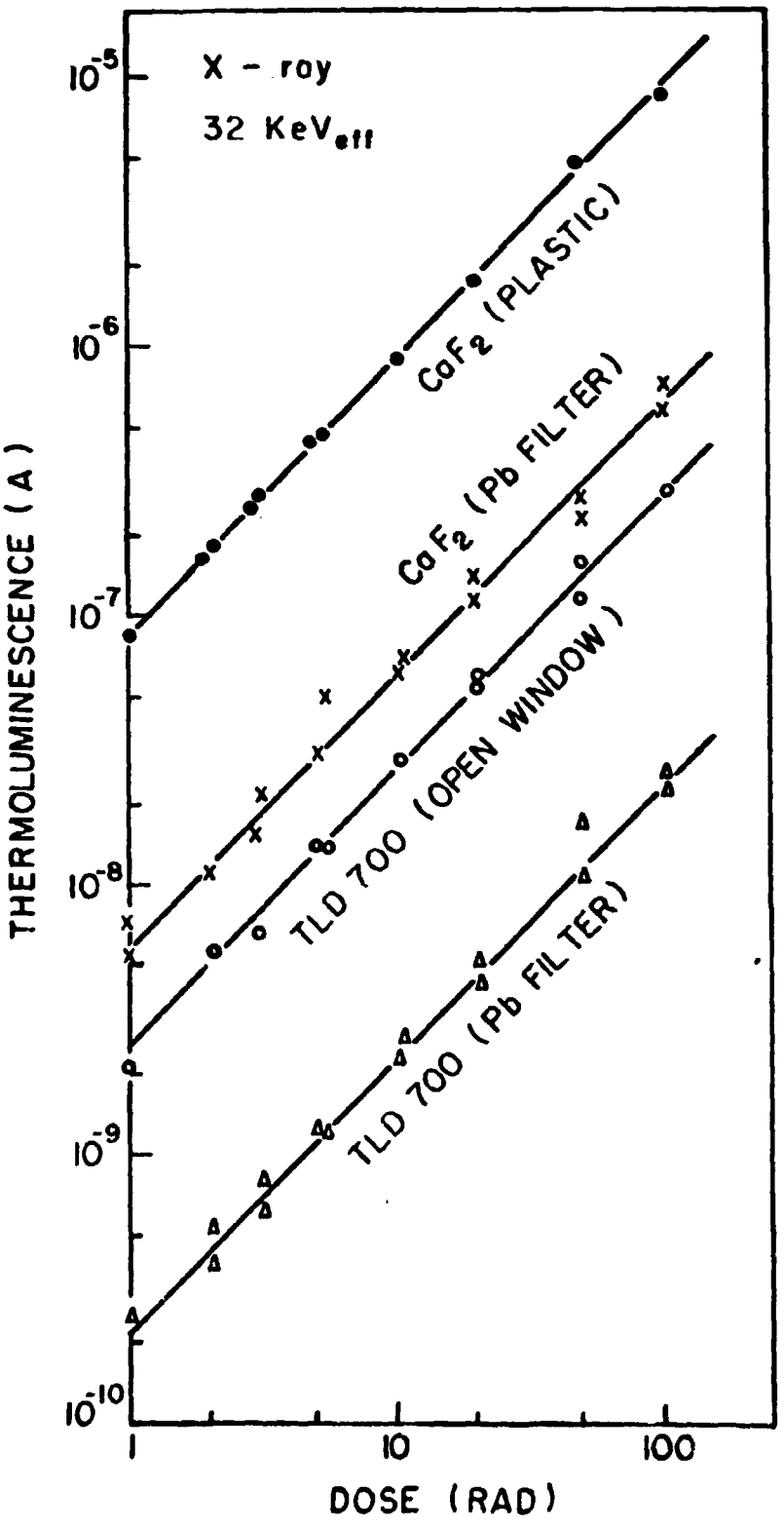
X - roy
32 KeV$_{eff}$
CaF_2 (PLASTIC)
CaF_2 (Pb FILTER)
TLD 700 (OPEN WINDOW)
TLD 700 (Pb FILTER)
THERMOLUMINESCENCE (A)
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
1
10
100
DOSE (RAD)

Figure 6

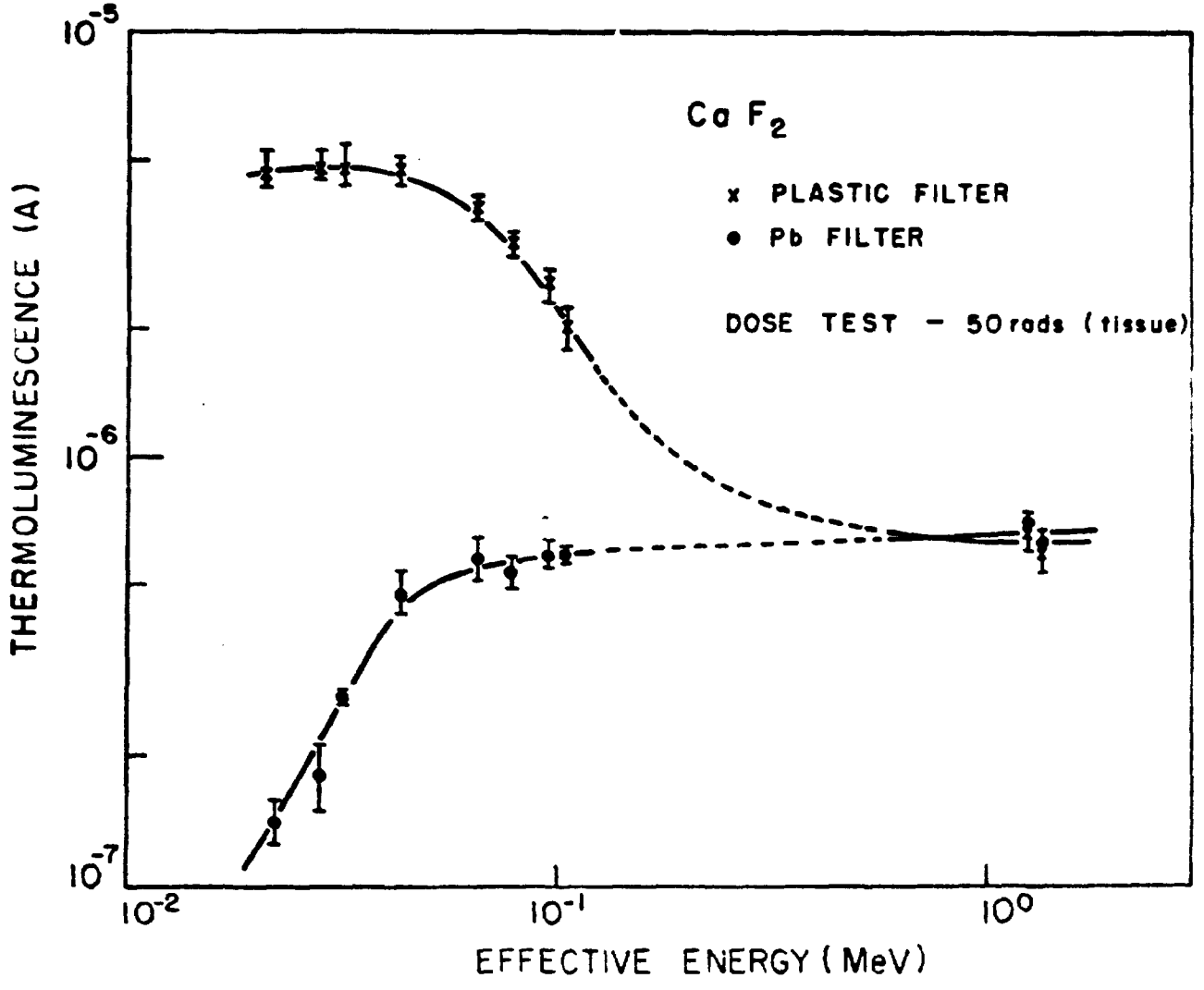
10^{-5}
10^{-6}
10^{-7}
THERMOLUMINESCENCE (A)
$Ca F_2$
x PLASTIC FILTER
• Pb FILTER
DOSE TEST - 50 rods (tissue)
10^{-2}
10^{-1}
10^{0}
EFFECTIVE ENERGY (MeV)

Figure 6

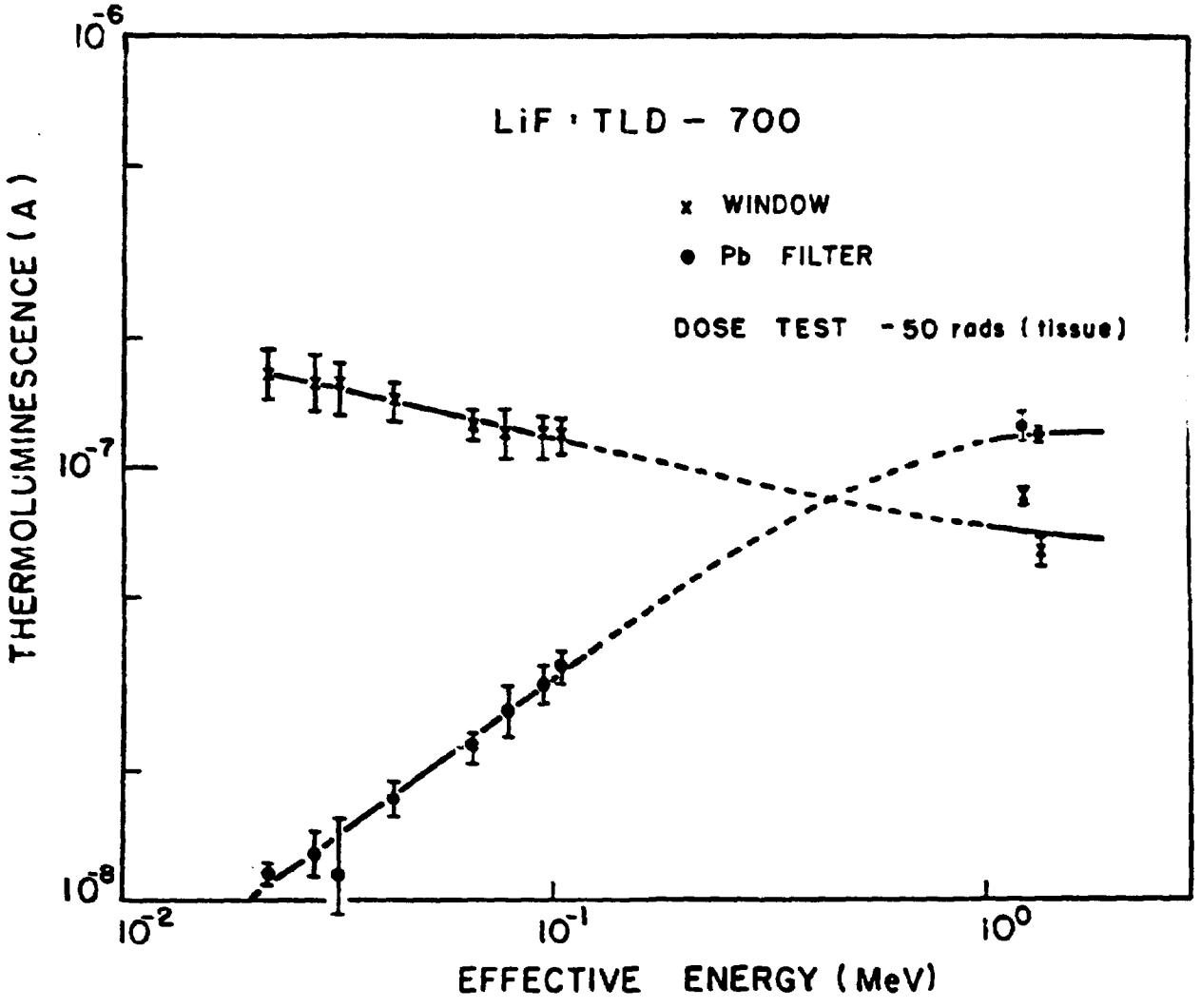
LiF : TLD – 700
x WINDOW
● Pb FILTER
DOSE TEST – 50 rads (tissue)
THERMOLUMINESCENCE (A)
10^{-6}
10^{-7}
10^{-8}
10^{-2}
10^{-1}
10^{0}
EFFECTIVE ENERGY (MeV)

Figure 7

RESUMO

Um novo método para preparar dosímetros TL na forma de discos sólidos, pela aplicação de uma pressão a frio numa mistura de KCl e fluorita em pó é investigado. Por este método é possível obter sem dificuldade milhares de dosímetros, muito mais uniforme do que os obtidos de monocristais.

Os resultados mostram que os novos dosímetros apresentam as mesmas propriedades que a fluorita em pó, com a vantagem do manuseio ser mais fácil nos trabalhos de rotina.

A razão de 2:1 para a massa de KCl: massa CaF_2 apresenta boa sensibilidade TL a radiação ionizante e suficiente resistividade mecânica. A exposição mínima detetável é aproximadamente 10 mR.

83% dos 442 discos sólidos de CaF_2 deram resposta TL dentro de 10% do valor médio. É também apresentada a dependência com a energia.

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